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THE FOOD OF DIFFERENT BIOLOGICAL FORMS OF THE DOLLY VARDEN CHAR, SALVELINUS MALMA (WALB.), IN CERTAIN KAMCHATKA WATERS

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In Lake Dalnee in June the principal food of the very small lake-stream malma was larval caddisflies and Chironomidae. More rarely they were feeding on molluscs [p. 128]. Still more rarely were found mayflies, ostracods, water bugs and Coleoptera. A relatively large amount of plant material was found in the stomachs, macrophyte material, which had no doubt been taken in accidentally along with the insect larvae (Table 2).

The principal food of large char in June is mollusca. Larval caddisflies occur also quite frequently but in weight they are of very little significance. In the food of the large fish a new component appears - the 3-spined stickleback and its eggs. Single specimens of Amphipoda and Hydracarina occur.

In July, in general, the same food ration is maintained. Among the very small fish, the larvae of aquatic insects predominate but still more important are the caddisfly larvae, with stickleback eggs occurring too (a heavy spawning of sticklebacks takes place in the lakes in July).

Table 1. The distribution of the material relating to the food of the various forms of S. malma.

Place of collection	Month and 10-day period of collection	Form			Dwarf males	Parr
		Lake-stream	Anadromous	Lake		
Paratunka River system Lake Dalnee and Dalnee River	June III	89(12)	24(1)	19(2)	--	--
	July I	47(3)	--	23	--	--
	II	33(10)	--	--	--	--
	Sept I	37(14)	--	--	--	--
	II	--	--	2	--	--
	III	35(8)	--	--	--	--
Total		241(47)	24(1)	44(2)	--	--
Lake Topolov	July I	--	--	--	--	11(1)
	III	--	--	--	4	--
	August	--	--	--	12	18(4)
	Sept I	--	--	--	17(1)	21(1)
	II	--	43(6)	--	--	--
Total		--	43(6)	--	33(1)	56(6)
Lake Azabache	August	40(9)	--	--	--	54(19)

Note: In parentheses are given the number of empty stomachs.

Very large char consume mainly molluscs, thus somewhat reducing the role of the caddisflies. In weight the amount of fish food increases; fish were found in two stomachs (coho and 3-spined sticklebacks); it can be said that fish occur rarely.

Salvelinus malma (Walb.) is a species with an extensive intraspecific variability. In Kamchatka waters it is represented by a number of biological forms. The principal ones are: 1) a typical anadromous malma which spawns in rivers and lakes and develops and feeds in the ocean; 2) a lake-stream form, closely related to the preceding but never going to sea; 3) a lake-living malma, which never leaves the lake during its lifetime. The anadromous form, like the anadromous salmon of the genera Oncorhynchus and Salmo, has dwarf males.

The above-named forms differ in morphological features, and in biological ones also, particularly with regard to their food. Very little is known regarding the food and feeding of malma. No investigations, dealing specifically with this question, have been carried out, with the exception of the studies of R. S. Semko (1948, 1954a). In the majority of cases there is only fragmentary information, based on a limited amount of incidentally-obtained material (Kuznetsov, 1928; Pravdin, 1928, etc.). The principal weakness in all these studies is the fact that no one realized that there were different biological forms of malma.

The aim of the present study is to examine the nature of the food of the several forms of malma in certain bodies of water in Kamchatka. The material was collected in the Paratunka River system in the summer and autumn of 1959 and in Lake Azabache (Kamchatka River system) in August of that year[1].

In Lakes Dalnee and Topolov the fish were caught with nets, at Lake Azabache - in traps. In the Dalnee River the malma were caught in the traps of the counting weir, the dwarf males and parr in traps and Kinaleb nets. [According to Dr. Krogius, who was asked to describe the "Kinaleb" net, it is made of small mesh material fastened to a four-sided metal framework and placed in the stream current to catch small fish.] In all cases the food was in a good state of preservation.

The apportionment of the material is shown in Table 1.

In all, 529 stomach contents were examined. Of these, 91 contained no food. In the examination the quantitative weight method (Brotskaya and Zenkevich, 1939; Shorygin, 1952; Zheltenkova, 1955) was used.

Food of the lake-stream char

Little is known regarding the food of the lake stream forms of char of the different species. In Lake Taimyr the lake-stream char, Salvelinus drjagini Logaschov were feeding on coregonids (Mikhin, 1955), the fresh-water form of Salvelinus alpinus L. of Littlefish Lake, on the 3-spined stickleback and bivalve molluscs of the family Sphaeridae (Sprules, 1952).

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[1]The study was made mainly at the field station of the Kamchatka Branch of TINRO on Lake Dalnee. The authors are most grateful to F. V. Krogius and E. M. Krokhin for much assistance and help in collecting material and for invaluable advice.

In late August and early September sockeye are spawning and in the food of the char there appears a new food item - sockeye eggs, which at once alters the food picture for the small char. The food spectrum becomes narrower. At this time it consists of three items: sockeye eggs, caddisfly larvae and molluscs; of these the eggs predominate.

In the food of larger char eggs occur rarely, the importance of molluscs increases while the quantity of caddisfly and chironomid larvae drops. Fish occur rarely (one coho).

In June and early July, together with the seaward-migrating anadromous char, some of the lake-stream malma move down-river. It is apparent that this is a feeding migration. In the river the role of caddisflies in the food of the lake-stream malma increases. The total index of stomach fullness among river-migrating fish is 83.0; in the fish staying in the lake it is 190.0. [See note at bottom of Table 2 re "total index of stomach fullness" and "partial index"].

Quite different is the feeding of the lake-stream char of Lake Azabache. Here adult fish are caught in August in the channel which connects [p. 129] the lakes with the Kamchatka River and in the lake itself from the mouth of the first fish-rearing spring to the sockeye spawning region. The food of the fish of the different sizes in these regions was not the same (Table 3). Small-mouth smelt made up the main food of small char in the channel, and molluscs constituted a much smaller share.

[p. 130] There were practically no young salmon in the stomachs; only one fish contained cohos. In the food of the large malma molluscs played the leading role (the species composition differing from that of the Lake Dalnee fish), drastically reducing the significance of fish as a food. The large char in the lake had been feeding almost wholely on terrestrial insects.

From the above it can be seen that the nature of the food of the lake-stream type of S. malma depends on the place of feeding, on the season and on the size. S. malma from Lake Azabache feed on fish (smelts), molluscs and terrestrial insects; in Lake Dalnee they consume larval aquatic insects, molluscs and salmon eggs. In Lake Dalnee the small char, during the summer, feed primarily on caddisfly and chironomid larvae, but in the autumn at the time of the salmon spawning they switch, to a considerable degree, to a diet of sockeye eggs. Very large malma, during the whole of the summer-autumn period, live on benthic organisms, mainly on molluscs.

The food of anadromous S. malma

Very little information is available on the food of the anadromous malma. As comparable material, we have some data relating to a very closely-related species - Salvelinus alpinus. In the sea Salvelinus alpinus feeds mainly on fish. In different regions the food items are made up of different species: in Nova Zembla - young cod (Esipov, 1935), in Taimyrsky Gulf - Arctic cod (Mikhin, 1955), in Okkak Bay - sandlance, capelin, young gobies (Andrews and

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Table 2. The food of lake-stream char in Lake Dalnee (frequency of occurrence and partial index of stomach fullness).

Food item	Feature	June		July		September	
		Fish of 130-250 mm.	Fish of 250-300 mm.	Fish of 150-250 mm.	Fish of 250-300 mm.	Fish of 200-250 mm.	Fish of 250-300 mm.
Molluscs	Occurrence, %	22.0	82.5	59.3	83.0	50.0	84.5
	Partial index	23.30	132.00	23.40	61.20	21.00	134.00
Larvae of:							
Caddisfly	Occurrence, %	80.7	78.5	96.3	55.0	89.0	34.2
	Partial index	29.80	21.40	92.30	9.35	25.60	2.23
Chironomidae	Occurrence, %	50.0	21.6	25.9	20.6	5.5	6.2
	Partial index	0.70	0.12	0.80	0.43	0.01	0.006
Mayfly	Occurrence, %	7.7	--	--	--	--	--
	Partial index	0.20	--	--	--	--	--
Amphipods	Occurrence, %	--	--	--	--	--	3.1
	Partial index	--	--	--	--	--	0.06
Eggs of:							
Stickleback	Occurrence, %	--	15.7	7.4	6.9	--	--
	Partial index	--	7.86	4.95	1.70	--	--
Sockeye	Occurrence, %	--	--	--	--	94.5	12.5
	Partial index	--	--	--	--	97.20	3.84
Vegetation	Occurrence, %	15.4	19.6	18.5	13.8	5.5	--
	Partial index	4.05	0.94	1.49	4.04	0.06	--
Fish	Occurrence, %	--	0.2	--	10.3	--	3.1
	Partial index	--	0.41	--	14.60	--	4.95
Miscellaneous	Occurrence, %	--	--	--	--	--	--
	Partial index	1.11	0.06	0.01	0.10	--	--
Total index of stomach fullness		59.16	162.79	121.95	91.42	143.87	145.086

Note: Total and partial indices calculated without counting empty stomachs.

["Total index of stomach fullness" is defined by Dr. Krogius in a personal letter as "the weight of the stomach content expressed as a percentage of the weight of the fish × 10,000 ; partial index of stomach fullness is the weight of the separate food constituent, expressed also as a percentage of the weight of the fish × 10,000".]

[p. 129]

Table 3. Food of lake-stream malma in August in Lake Azabache (frequency of occurrence and partial index of stomach fullness).

Food item	In channel		In channel		In Lake	
	Fish, 150-250 mm.		Fish, 250-400 mm.		Fish, 300-400 mm.	
	Occurrence %	Partial index	Occurrence %	Partial index	Occurrence %	Partial index
Limnaea auricularis	8.3	33.2	50.0	188.0	--	--
Sphaerium corneum	--	--	16.6	20.4	--	--
Limnaea catascopium	--	--	16.6	--	--	--
Mollusca	8.3	33.2	83.2	208.4	--	--
Hypomesus olidus	83.0	430.0	25.0	78.5	--	--
Oncorhynchus kisutch	8.3	4.7	8.3	3.25	--	--
Diptera fam. Bibionidae	--	--	--	--	43.5	45.4
Total index of stomach fullness	471.0		290.0		20.0	

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Lear, 1956). In Frobisher Bay, along with various invertebrates, occur Myoxocephalus groenlandicus, Triglops pingeli, Eumicrotremus spinosus, Liparis sp., Ammodytes sp., Boreogadus saida and the young of Salvelinus alpinus (Grainger, 1953), in Hudson's Bay - sandlance (Sprules, 1952). In fresh water Salvelinus alpinus feeds, apparently, on the same varieties of food; in Gydansky Gulf the food consisted of crustaceans, larval Coleoptera, caddis worms, Mesidothea, lemmings, and others (Rudakova, 1941).

The main food of anadromous S. malma in the ocean consists of Hypereidae and fish (Andrievskaya, 1957). In fresh water the anadromous S. malma in certain areas consumes young salmon and salmon eggs (Semko, 1948, 1954).

In Lake Dalnee the chief food item of the seaward-migrating anadromous char in June was chironomid larvae and pupae, larval caddisflies, mayflies and stoneflies; molluscs were rare (Table 4). During the migration the char continue to feed but the total index of fullness at this time is quite low - 27 (29).

Unfortunately we do not have information on the food of anadromous S. malma returning from the sea to Lake Dalnee, therefore we must use data on the food of anadromous char in September from Lake Topolov (Paratunka River system). In the food of tiny char the leading place is taken by chironomid larvae and other aquatic insect larvae. Detritus, of course, is taken in accidentally with these larvae. In the food mass are found relatively many

Cladocera. The very small percent of terrestrial insects indicates that these fish are feeding primarily off the bottom.

In the food of large char terrestrial insects play an important role. These consist of Hymenoptera, Diptera and other insects which inhabit the shallow water vegetation. Among the aquatic insect larvae more often the large larvae occur; mayfly, stonefly, Coleoptera, less often chironomids. In the stomach contents only one fish was found; undoubtedly this was a small S. malma, since salmon do not occur in this lake. There are no sticklebacks in the lake.

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Table 4. Food of anadromous char.
(Frequency of occurrence and partial index of stomach fullness)

Food components	Lake Topolov				Lake Dalnee	
	Fish, 150-250 mm.		Fish, 250-350 mm.		Fish, 150-250 mm.	
	Occurrence %	Partial index	Occurrence %	Partial index	Occurrence %	Partial index
Terrestrial insects	52.0	3.20	57.0	6.65	--	--
Larvae:						
Chironomidae	84.5	8.80	78.5	2.16	91.4	18.30
Mayflies	34.8	1.70	50.0	3.06	8.4	1.83
Stoneflies	26.1	0.50	57.0	2.16	4.3	0.96
Dytiscids	13.1	0.60	21.4	0.95	--	--
Water bugs	8.7	0.40	21.4	1.30	--	--
Cladocera	65.2	5.10	57.0	4.45	--	--
Molluscs	52.0	2.30	28.0	0.44	13.0	5.05
Fish	--	--	7.1	2.30	--	--
Vegetation	17.4	1.45	7.1	0.004	13.0	0.37
Detritus	30.5	7.98	7.1	0.04	--	--
Larval caddisflies	--	--	--	--	17.4	2.79
Miscellaneous	--	0.34	--	0.87	--	0.36
Total index of stomach fullness	32.37		24.384		29.66	

In general, the principal foods of the anadromous char in Lake Topolov are benthic insect larvae and terrestrial insects.

Small char feed on aquatic insect larvae, the species composition of which is quite different from those eaten by the small char of the lake-stream type. Larger char feed mainly on terrestrial insects.

The food of the lake-resident char

The lake-resident S. malma are closely related to the various so-called trout of Europe, Siberia and America. In the majority of regions they are predators (Mikhin, 1955; Lobovikova, 1959; Greze, 1953; Podlesnyi and Lobovikova, 1953; Miller and Kennedy, 1948).

In accordance with the location and nature of the basin in which they occur the trout feed on various species of fish: in the Taimyrsky Lakes - primarily on the young of various whitefish, in Great Bear Lake - on pike burbot, trout, whitefish, etc. In Lake Dalnee the lake-resident char are typical predators with a narrow food spectrum. Their chief food is the 3-spined and 9-spined sticklebacks (Table 5). Amphipods are very rarely taken, as are also molluscs, caddisfly and chironomid larvae. Among those fish longer than 300 mm., only fish were eaten. According to the nature of the food of this type of char it can be presumed that it feeds mainly throughout quite a deep stratum of water.

Our data on the food of the lake S. malma pertain mainly to the June-July period. From less numerous specimens, caught in the autumn, the stomach contents consisted of sticklebacks: fish with gonads in the 5th stage, had empty stomachs. It is thus obvious that at spawning time the lake char do not feed. Data on the food of lake char for earlier years, kindly provided to us by F. V. Krogius and E. M. Krokhin, confirm the above findings as to the food of the lake char. Only occasionally were young sockeye found in the stomachs of large fish. Sticklebacks are a competitor of young sockeye for plankton food and [p. 132] therefore the lake char play a definitely important role, by destroying the competitor (Krogius and Krokhin, 1948, 1956).

Lake char, as distinct from the anadromous and lake-stream types, feed almost exclusively on fish.

Table 5. Food of the lake-resident char in Lake Dalnee)
(Frequency of occurrence and partial index of stomach fullness)

Food item	June		July	
	Occurrence %	Partial index	Occurrence %	Partial index
Gasterosteus aculeatus, Pungitius pungitius	88.4	94.10	91.3	120.00
Gammarus lacustris	23.5	5.35	8.7	1.63
Valvata sibirica, Planorbis sp., Radix sp. - Leptocerus annulicornis (Limnophilidae)	24.9	1.40	1.3	0.98
Apatania (Trichoptera)	29.4	2.64	8.7	0.18
Vegetation	11.7	1.60	8.7	0.14
Miscellaneous	--	0.53	--	1.41
Total index of stomach fullness	105.62		124.34	

Table 6.

Food of young char.

(Frequency of occurrence and partial index of stomach fullness)

Food item	Particulars	Blizhnee Spring (young) 80-170 mm.			Dwarf males	Lotnaya River (young)	
		July	Aug.	Sep.		110-150 mm.	150-200 mm.
Terrestrial insects	Occurrence, %	80.0	85.6	90.3	81.3	22.0	18.2
	Partial index	36.9	30.2	172.0	47.70	74.11	71.00
Larvae:							
Mayfly	Occurrence, %	100.0	28.6	15.0	43.8	28.0	4.5
	Partial index	33.0	1.5	1.5	9.30	13.40	1.94
Caddisfly	Occurrence, %	50.0	7.1	90.03	46.8	--	--
	Partial index	10.07	0.95	169.0	21.80	--	--
Stonefly	Occurrence, %	30.0	21.4	40.0	40.6	--	--
	Partial index	6.2	2.5	10.0	5.42	--	--
Chironomidae	Occurrence, %	70.0	50.0	90.3	68.7	--	--
	Partial index	5.6	1.1	14.2	5.55	--	--
Simulidae	Occurrence, %	--	--	--	--	3.1	--
	Partial index	--	--	--	--	1.23	--
Water bugs	Occurrence, %	--	--	--	3.1	3.1	4.5
	Partial index	--	--	--	4.12	0.61	1.94
Water mites	Occurrence, %	20.0	14.3	20.0	21.8	3.1	4.5
	Partial index	0.1	0.1	0.3	0.18	0.61	0.88
Fish, eggs	Occurrence, %	--	14.3	15.0	3.1	3.1	--
	Partial index	--	2.1	22.3	11.40	0.61	--
Vegetation	Occurrence, %	--	--	10.0	9.4	--	--
	Partial index	--	--	1.1	0.16	--	--
Oligochaeta	Occurrence, %	--	--	--	--	3.1	--
	Partial index	--	--	--	--	1.23	--
Miscellaneous	Occurrence, %	--	--	--	--	3.1	--
	Partial index	0.05	--	1.2	--	0.61	--
Total index of stomach fullness		92.55	38.45	391.6	105.63	92.41	75.76

[p. 133] Food of the young and dwarf males of S. malma

Our study has included the food of the young and dwarf males of S. malma from several springs in the Paratunka River system and from the Lotnaya River, which flows into Lake Azabache. In the Paratunka River system the chief food of the young in July is aquatic insect larvae, particularly mayfly larvae. In August the importance of terrestrial insects increases notably, and they represent a large part of the food ration (Table 6). In the stomachs of two fish were found quite small char, one specimen being 30-40 mm. long. In September, as before, the main item was again terrestrial insects and larvae of aquatic insects (mainly caddisfly). There appears a new component - the eggs of char. In the food of the young from the Lotnaya River, aquatic insect larvae predominate, primarily chironomids, and terrestrial insects were less frequent. The food of the dwarf males was much the same as for the young fish: terrestrial insects, larvae of aquatic insects, water bugs and mites, but fish (char) occurred rarely.

In the nature of their food, the young and the dwarf males of S. malma closely resembled the young of Salvelinus alpinus (Retovsky, 1935) and the young and dwarf males of Atlantic salmon (Nikolsky and others, 1947). The dwarf males continue to feed at spawning time. Somewhat similar results were obtained by V. V. Chernavin (1921) in regard to creek forms of trout. During the spawning period the total index of stomach fullness is somewhat reduced. For fish with IV stage gonads it is 93; when the eggs are ripe and running it drops to 41 but after spawning it rises again to 96 or more.

Appendix 1

Composition of food of anadromous char (Lake Topolov), n = 35

	Number per stomach	Frequency of occurrence, %
Larvae Chironomidae		
Tanytarsus sp.	0.8	11.4
Tanytarsini gen. sp.	0.7	8.5
Chironomus sp.	12.5	37.2
Brillia sp.	0.3	5.7
Diamesa sp.	0.3	5.7
Larvae Ephemeroptera		
Baetis sp.	3.0	34.4
Heptageniidae gen. sp.	0.3	11.4

Appendix 2

Composition of food of lake-stream char (Dalnee River and Dalnee Lake), n = 204

	Number per stomach	Frequency of occurrence, %
Mollusca		
Valvata sibirica	14.7	34.3
Valvata stelleri	1.4	6.8
Planorbis planorbis	4.1	18.1
Planorbis carinatus	0.3	2.4
Pisidium sp.	0.1	3.9
Radix sp.	6.2	41.1
Larvae Chironomidae		
Stempelina gr. bausei	0.6	1.0
Limnochironomus sp.	0.1	3.0

Appendix 1 (cont'd)

Larvae Plecoptera		
Fam. Perlidae	1.3	40.0
Larvae Dytiscidae	--	17.1
Hemiptera	0.6	14.3
Mollusca		
Genus Pisidium	2.4	45.7
Cladocera		
Alonopsis	--	65.7
Ostracoda	0.7	22.8
Lepidoptera, Diptera, Coleoptera and misc. terrestrial insects	36.5	54.2
Vegetation	--	14.3
Detritus	--	22.8

Occurring only once: Orthocladiinae gen. sp. larvae Trichoptera, Gammarus, Hydracarina, Pisces

Appendix 2 (cont'd)

Orthocladiinae gen. sp.	0.4	1.0
Diamesa pseudostylata	1.0	7.3
Gen. sp.	1.8	8.9
Larvae Trichoptera		
Leptocerus annulicornis	12.2	27.4
Glyphotaelus sp.	0.7	2.9
Limnophilinae gen. sp.	2.1	14.2
Gen. sp.	2.4	19.6
Hydracarina	0.2	7.9
Stickleback eggs	7.0	5.8
Sockeye eggs	1.5	10.3
Vegetation	--	12.2

Occurring only once: Tanytarus sp., Chironomus gr. heterodentatus, Limnochironomus gr. tritomus, Cricotopus sp., Diamesa sp., Syndiamesa gr. nivosa, Pelopiinae gen. sp., Leptoceridae gen. sp., Apatania sp., Agreylea sp., Baetis sp., Ameletus camtschaticus, Ephemerella, Heptageniidae gen. sp., Dytiscidae, Gammarus lacustris, Ostracoda, Pisces.

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Appendix 3.

Composition of food of lake-resident char (Lake Dalnee), n = 40

	Number per stomach	Frequency of occurrence, %		Number per stomach	Frequency of occurrence, %
Mollusca			Larvae Trichoptera		
Valvata sibirica	0.2	7.5	Leptocerus annulicornis	2.0	15.0
Planorbis planorbis	0.3	7.5	Larvae Chironomidae		
Radix sp.	--	5.0	p. Ablabesmyia	0.4	5.0
			Vegetation	--	5.0

Occurring only once: Radix sp., Apatania sp., Limnophilina gen. sp., Plecoptera larvae.

Conclusion

1. Anadromous, lake-stream and lake forms of char differ in the character of their food. The anadromous char feed mainly on terrestrial insects and aquatic larval forms of insects, the lake-stream - principally on molluscs, the lake-resident - are predaceous.

2. For each biological form the character of the food varies according to the size of the fish, the season and the actual conditions prevailing in the area inhabited.

3. The results obtained confirm the conclusions reached earlier by F. V. Krogius and E. M. Krokhin (1948, 1956) that char are not always harmful to other fish. In the regions examined the char consume smelt and sticklebacks, which are food competitors of young sockeye, and thus they are more beneficial than harmful. Since they feed on the eggs of salmon the char may be considered to play a "sanitary" role on the spawning grounds, destroying that which must inevitably die, i.e., those eggs which are washed away during spawning and during the digging up of the redds by later-arriving salmon.

4. There is a wide variability in the food of the various forms of char. Each has a specific type of food, natural for each form and permitting it to occupy a different food niche. On the whole, this serves to assure the full utilization of the diverse food resources of the waters.

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